SPECIAL REPORT

UNDERWATER SYSTEMS GROUP

SURVEY OF PORTABLE RANGE TECHNOLOGIES

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SPECIAL REPORT

SURVEY OF PORTABLE RANGE TECHNOLOGIES

OCTOBER 2005

Prepared by

UNDERWATER SYSTEMS GROUP (USG)
RANGE COMMANDERS COUNCIL

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PREFACE

This report presents the results of Task US-17 "Survey of Portable Range Technologies" by the Underwater Systems Group (USG) of the Range Commanders Council (RCC). A copy of the Task US-17 assignment can be seen at Appendix A. The information contained herein is a compilation of information obtained from USG associate and member ranges that conduct shallow-water Undersea Warfare (USW) testing and training and/or who provide facilities for test and evaluation. The objective of this effort is to document the different methods and systems currently being used or developed to perform portable range tracking functions. The information in this report will facilitate the decision process for selecting the type of portable range system that is best suited for a particular application given a specific test site and its environmental information. The advantages and disadvantages of each system are addressed and are summarized in a matrix of attributes against range requirements.

The USG would like to provide a special acknowledgement for production of this document for the RCC to the following individuals:

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Co-author: Mr. Neal Prater, Naval Undersea Warfare Center Division (NUWCDIV), Keyport, WA

Note: A special acknowledgement is also given to Mr. Richard Peel Naval Undersea Warfare Center Division (NUWC Division, Keyport, WA).

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CHAPTER 1

INTRODUCTION

The United States (U.S.) Navy has applied a variety of technologies to address a myriad of needs for Undersea Warfare (USW) systems in littoral regions. To accommodate the need to test and evaluate weapon system performance in actual or surrogate environmental conditions, the Naval Undersea Warfare Center (NUWC) has developed portable temporary range systems. These portable range systems were developed under sponsorship from the Chief of Naval Operations (CNO) Director of Test & Evaluation & Technology/Requirements, the Naval Air Systems Command (NAVAIR), and the Naval Sea Systems Command (NAVSEA) Test & Evaluation Office. At these portable ranges, as is the case for the Navy's fixed location tracking ranges, the participant platforms (surface ships, submarines, and unmanned undersea vehicles) and weapons (torpedoes, targets, etc.) must be located and tracked in three dimensions. Tracking in three dimensions is required to ensure range safety and to facilitate post-exercise system performance analysis.

New applications for such portable acoustic detection systems have also been deployed to perform splash impact detection and scoring for naval gunfire exercises and training purposes.

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CHAPTER 2

CHALLENGES OF THE LITTORAL ENVIRONMENT

2.1 The Need for Portable Tracking and Measurement Systems

The requirement for portable tracking and measurement systems in littoral environments was born from the need to conduct fleet training as well as research, development, test, and evaluation (RDT&E) under a variety of environmental conditions that exist globally. The need for the Navy's established fixed-site ranges has not diminished, but the additional requirement to also conduct surrogate site testing in these sometimes unique complex environments has established the need for portable range systems.

Acoustic signal processing is the primary method for sonar detection as well as for underwater tracking. Highly reverberant shallow water, typical of many near-shore or littoral regions, poses an especially difficult acoustic problem for today's undersea system designers and fleet units. When propagating through the water, acoustic energy often bounces from both the surface and the sea floor. In shallow water, this can cause the acoustic signals to travel over many individual bounce paths between the source and the receiver. This "multipath" acoustic environment presents significant signal processing challenges for both weapon system developers and range instrumentation designers. In addition, the effects of varying sound speed profiles, noise, wave action, and changing bottom conditions come into play when designing, installing, and operating portable range systems. Deep-water locations also provide different challenges such as instrumenting large areas (100-200 nmi2) suitable for training, and very deep locations (up to 6000m).

2.2 Technical Solutions for Littoral Tracking

The key technical solutions for reliable acoustic tracking and splash point detection in littoral regions required development of specialized components and capabilities:

a. Multipath tolerant acoustic tracking signals and signal processing methods
b. Rapidly-deployed, modular, and economical, sensor array systems
c. Portable range tracking centers, with tracking computer software optimized for shallow water environments
d. Full integration of surface/air tracking with underwater tracking results
e. Real-time remote displays of system results

The advent of powerful, yet portable, computers and digital signal processors contributed to the development of transportable range tracking systems. Depending on system configuration, an entire suite of tracking equipment can now fit into a few carry-aboard equipment cases for ship-based range operations. Alternately, a complete Portable Range Operations Center (PROC) van can be placed on the deck of a ship or at a shore site. Tracking software algorithms used at the fixed-site ranges were adapted, approved, and improved to meet multipath challenges of littoral range sites.

The Differential Global Positioning System (DGPS) has provided an ideal solution for surface and in-air tracking at portable range sites. Real-time, three-dimensional positions are reported from DGPS-equipped vessels or aircraft via radio telemetry links and merged with the underwater object positions. Knowing the positions of all tracked objects allows them to be recorded and shown together on the range display screens.

Finally, improvements in data communication technology, coupled with portable laptop computers and display projection systems, have made it practical to remotely display tracking data of range exercises almost anywhere in the world, as they happen.

2.3 System Configuration Alternatives

In order to meet the differing requirements for ranges at diverse sites, and with multiple operating scenarios, a number of portable range system solutions have been developed. The range system and its components are selected for a particular application based upon the environmental constraints, bathymetry, bottom topography, size, distance from shore, duration of use, and cost.

The factor that most significantly affects the cost and complexity of a portable range is the configuration of its sensor array. The in-water sensor arrays used with NUWC range systems are described in the following subparagraphs; they are typically of four types.

a. Individual sensors linked by Radio Frequency (RF) buoy (includes moored, free floating, and station keeping variants)
b. Bottom deployed transponders with near surface receiver (range support craft or station keeping buoy)
c. Individually cabled sensors
d. In-line-cabled multiplexed strings of sensors

2.3.1 Individual sensors linked by RF buoy. The most economical array type is comprised of radio-linked, buoyed sensors; this array type is effective for smaller short-term installations where buoy-mooring cables are acceptable. Each sensor in the array is placed on the sea floor, and a small-diameter cable connects it to a buoy moored above it (see Figure 2-1).

The buoys contain batteries and a radio transmitter to send the received in-water tracking signals to a nearby tracking center, which houses the signal processors, tracking computer, and displays. The version of the buoyed approach which has been used extensively is moored to the bottom, with the sensor located at the anchor or offset by as much as 2 km from the buoy mooring. A free drifting variant has been developed which adds a GPS sensor to the buoy and left to drift in the current. The SSQ-53 sonobuoy now has a GPS variant which can also be used as a free floating range sensor suitable as either an air deployed or surface deployed range. A station keeping variant of the RF buoy sensor has also been developed. The RF signal receivers and tracking center equipment can be on shore, aboard a moored barge or surface ship, or in an aircraft.

A version of the free-floating RF buoy sensor has been used in a splash detection range to facilitate training of surface ship gunfire crews. The system is deployed by the ship's crew and the projectiles fired from the ship's gun impact the area within the sensor field. The location is calculated and referenced to specified target locations, corrections passed to the gun crew, and additional rounds fired.

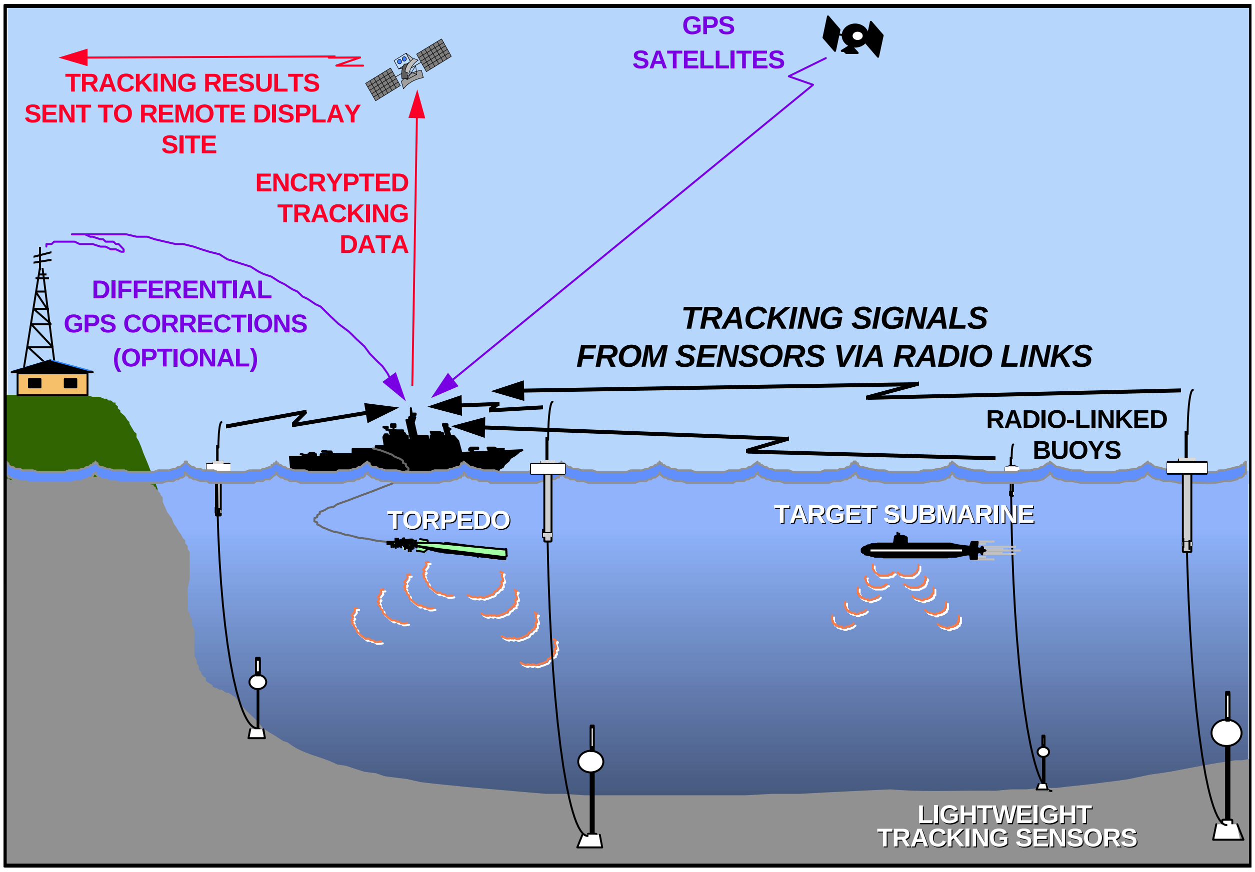

Figure 2-1. A portable range using radio-linked buoyed sensors.

2.3.2 Bottom deployed transponders with near surface receiver. This method installs the range sensor on the bottom and communicates the detection of valid tracking signals using acoustic communication techniques (Figure 2-2). These transponders can use acoustic communications schemes as simple as tone pulses, to complex data communications utilizing encoded signals carrying data. A near surface acoustic receiver and signal processor combine all the transponder detections into a tracking solution. This receiver can be either located on a range support craft drifting near the center of the range, or a station keeping buoy to receive the acoustic signal and transmit them via RF channel to shore or to a range craft located off the range.

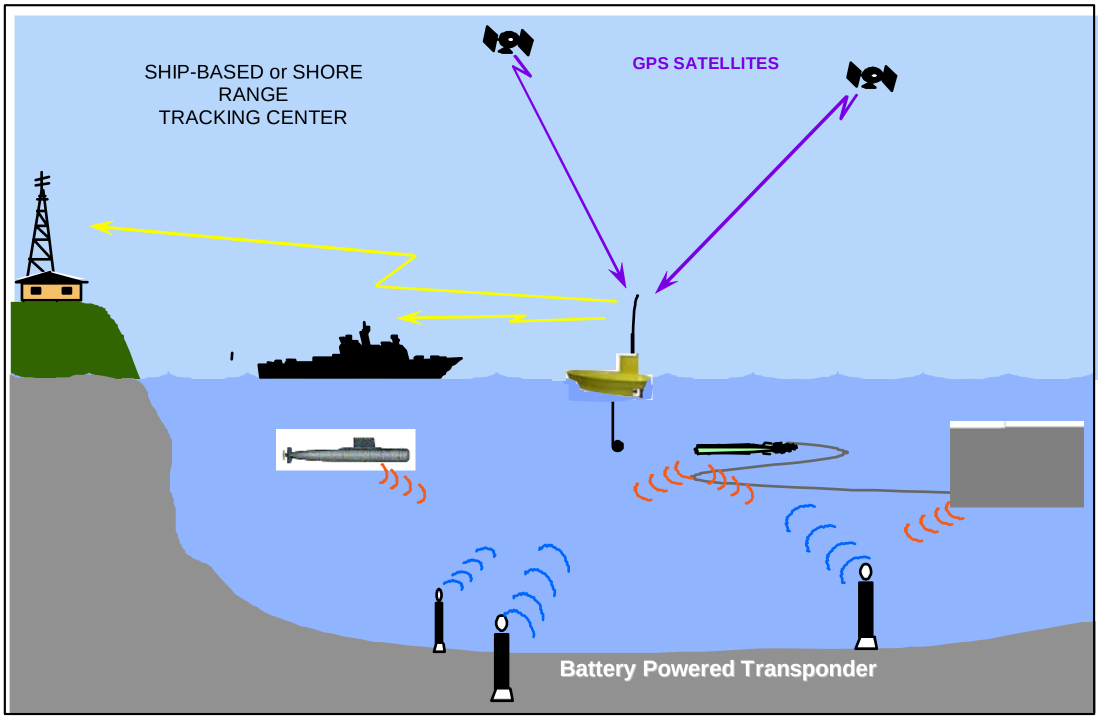

Figure 2-2. Transponder based range.

2.3.3 Individually cabled sensors. Cables (typically 1/4 inch in diameter) deployed along the sea floor carry the signals from each sensor to the tracking center, or alternatively, to a central multiplexer which then sends the signals to the tracking center using a single trunk cable. These arrays are useful when longer-term installations are needed, or when the radio telemetry buoys, or their riser cables, might present a hazard to navigation for submarines or surface ships.

2.3.4 In-line-cabled multiplexed strings of sensors. The most complex method uses in-line strings of sensors, multiplexing the signals from these sensors onto one electro-optical cable as shown in Figure 2-3. This method enables rapid installation of a relatively large tracking array, which can be left in place for years if necessary. Ranges can be configured with up to 100 sensors, using two string arrays each having up to 50 sensors and 50 nautical miles of cable.

Like the buoyed sensors, both of the cabled systems are retrievable for re-use. Their cables can be terminated at a portable tracking center located on shore or at a moored barge or surface ship. Alternately, for installations ranging from a few days to a few months in areas where a shore cable landing or use of moored ship is not convenient, a moored, remotely controlled, termination and telemetry buoy can be used, as shown in Figure 2-4.

Applications in high-risk areas (rough bottoms, high ship traffic area, or bottom fishing and trawling) will usually require the use of either inexpensive, expendable systems or extra cable protection. Even in benign environments, when extended duration is required, a more robust cable type may be needed for sufficient reliability and assured intact retrievability. Each portable range application tends to be unique, as does each installation site. For these reasons, the U.S. Navy systems are designed with sufficient flexibility to allow a wide variety of configurations, maximizing utility and minimizing installation costs.

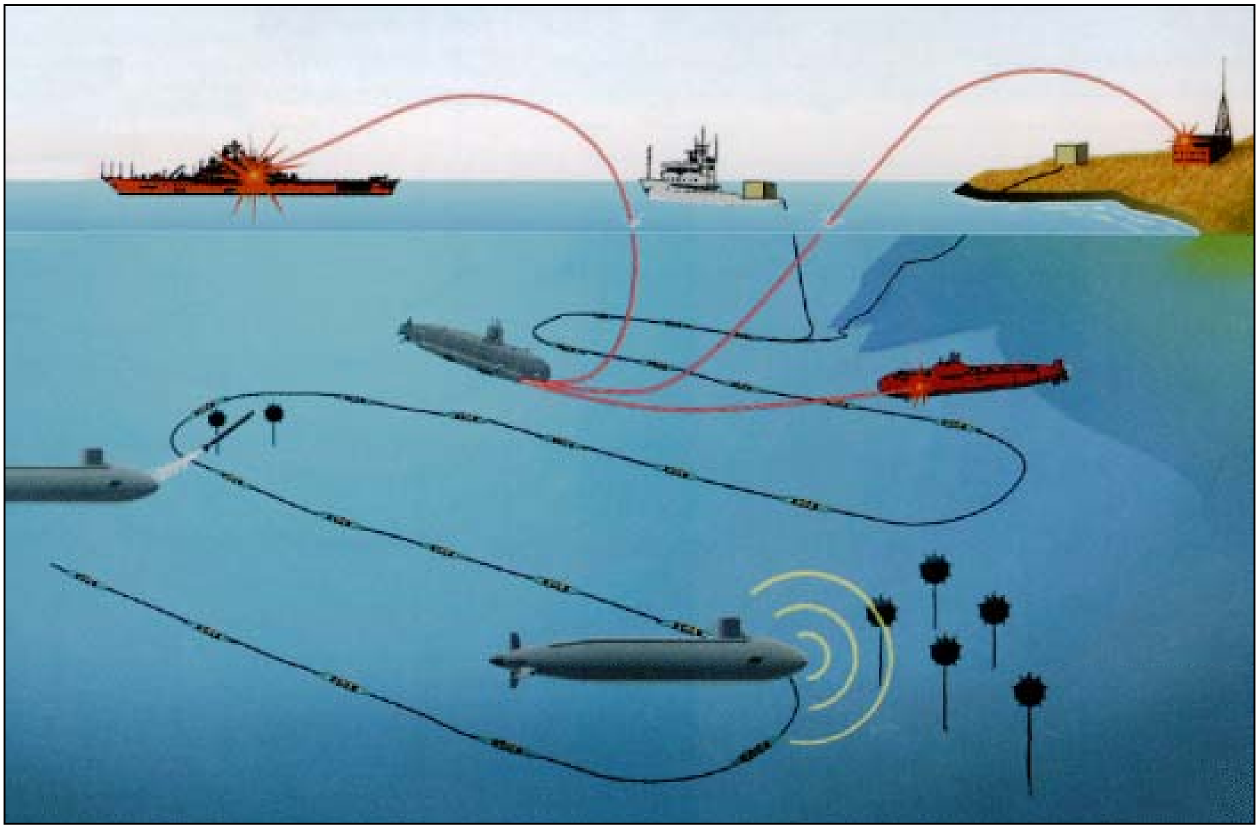

Figure 2-3. A multiplexed sensor array on a single fiber optic cable.

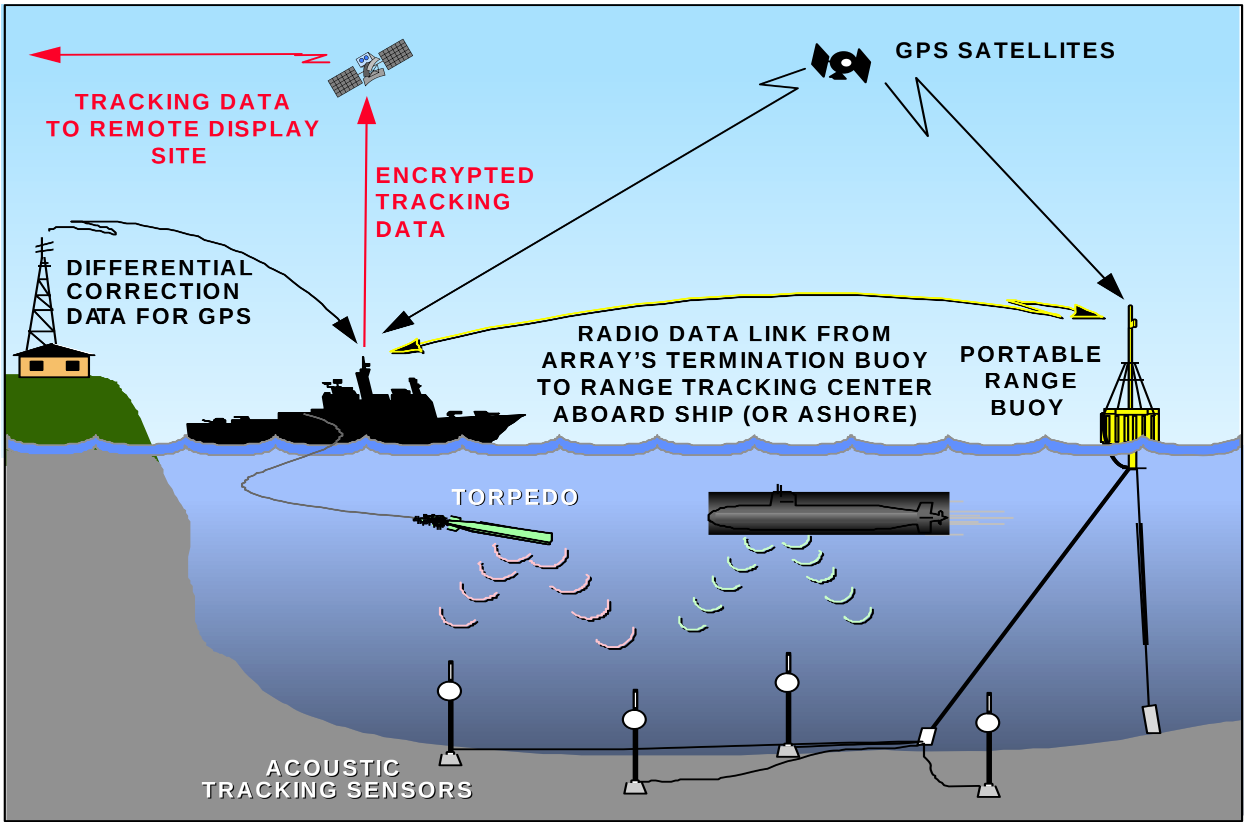

Figure 2-4. A buoy-based, cabled, portable range.

2.4 Performance Characteristics

The basic characteristics for the portable range configuration are detailed below. All systems can track up to five or six underwater objects. Track coverage is dependent on water depth and the number of sensors deployed.

2.4.1 <u>Radio-linked, buoyed sensor systems (moored)</u>

a. Up to 45 buoyed sensors
b. Water depths: 10 - 2400 feet
c. 100 operating hours per battery charge
d. Buoy "sleep" mode for extended battery life
e. Rapidly deployed from small craft
f. RF reception distance: 5+ nautical miles from buoys

2.4.2 <u>Free-drifting radio-linked surface buoy system</u>.

a. Water depths: 50- >15,000 feet
b. Sonobuoy-based designs with different packaging styles
c. Spar buoys with larger battery packs, GPS position reporting
d. Tactical-sized modified sonobuoys with GPS position reporting
e. Operating hours per battery set, or charge (8-30)
f. Rapidly deployed from small craft

2.4.3 Radio-linked, station-keeping surface buoy system (Figure 2-5)

a. Water depths: 50- >15,000 feet
b. Operating hours per battery charge (25+)
c. Can maintain position within programmable watch circles from 10-100 meters
d. Rapidly deployed from small craft

2.4.4 Transponder based sensor system

a. Water depths: 200- 15,000 feet
b. Operating time variable: days to months per battery set depending on configuration
c. Rapidly deployed from small craft
d. Requires moored (or a station keeping) surface buoy with sub-surface acoustic receiver and above water radio telemetry link

2.4.5 Individually Cabled Sensor Systems:

a. Options for cabling to a single radio telemetry buoy, moored boat or barge, or a shore site
b. Lightweight/low-cost cables or heavy-duty armored cables for extended service
c. Water depths: 5 - 2400 feet
d. Rapidly deployed from small craft

2.4.6 In-line Cabled Fiber Optic Sensor System:

a. Options for cabling to a moored boat, barge, or a shore site
b. Water Depths: 120 - 2000 feet
c. Modular (up to 100 sensors, with 2 arrays of up to 50 sensors each)
d. Robust and reliable for extended deployment

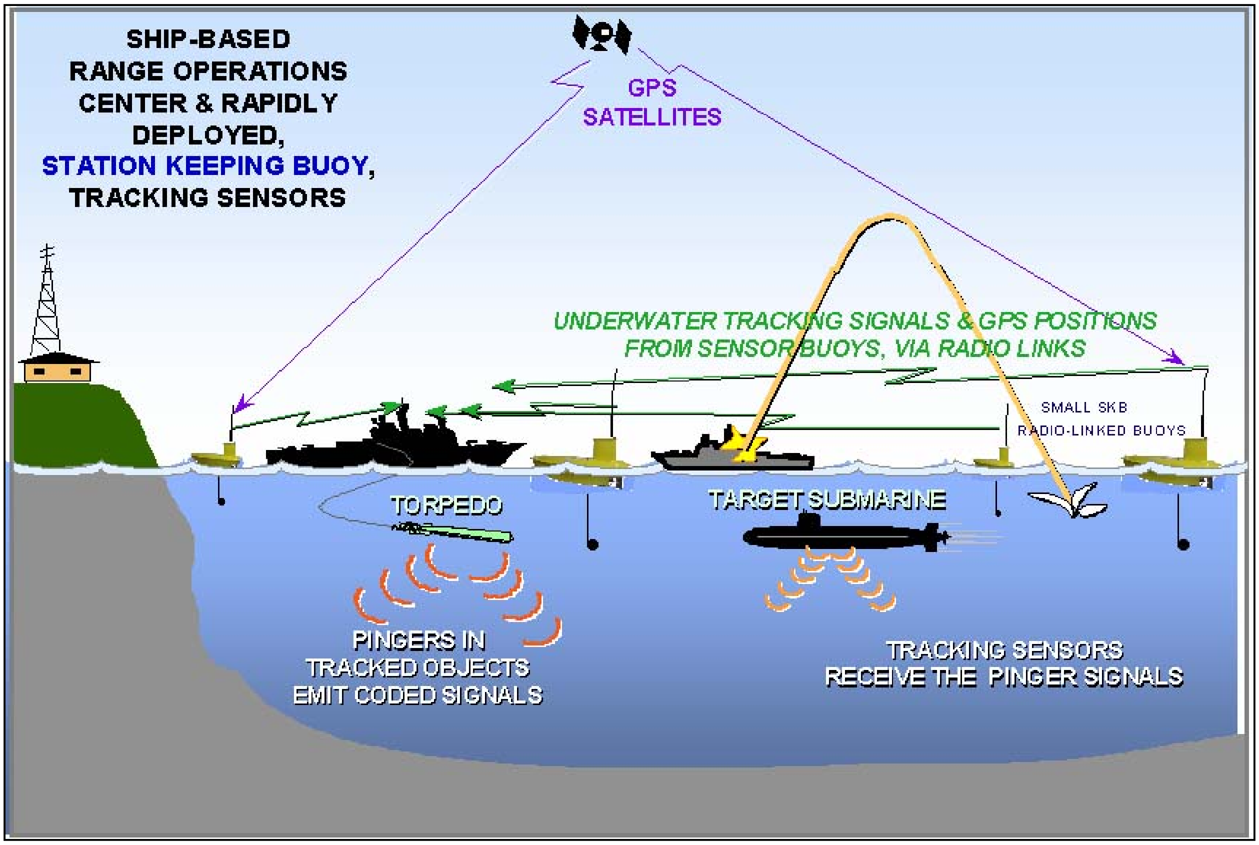

Figure 2-5. Station-keeping buoy approach.

2.5 Portable Range Installation Hardware

The U.S. Navy has deployed portable ranges in a variety of sites to support test & evaluation and training exercises. Some of these were temporary installations for a period of only a few days, after which the system was removed. Others have been in place for over two years. Illustrations of some of the representative shallow water tracking range hardware can be seen at the end of this chapter. The illustrations are as follows:

Figure 2-6	RF telemetry buoy being deployed
Figure 2-7	In-Line multiplexed sensor node and hydrophone
Figure 2-8	Cable deployment operation
Figure 2-9	Station-keeping buoy being deployed
Figure 2-10	Connecting the sensor cables to a portable range termination and telemetry buoy

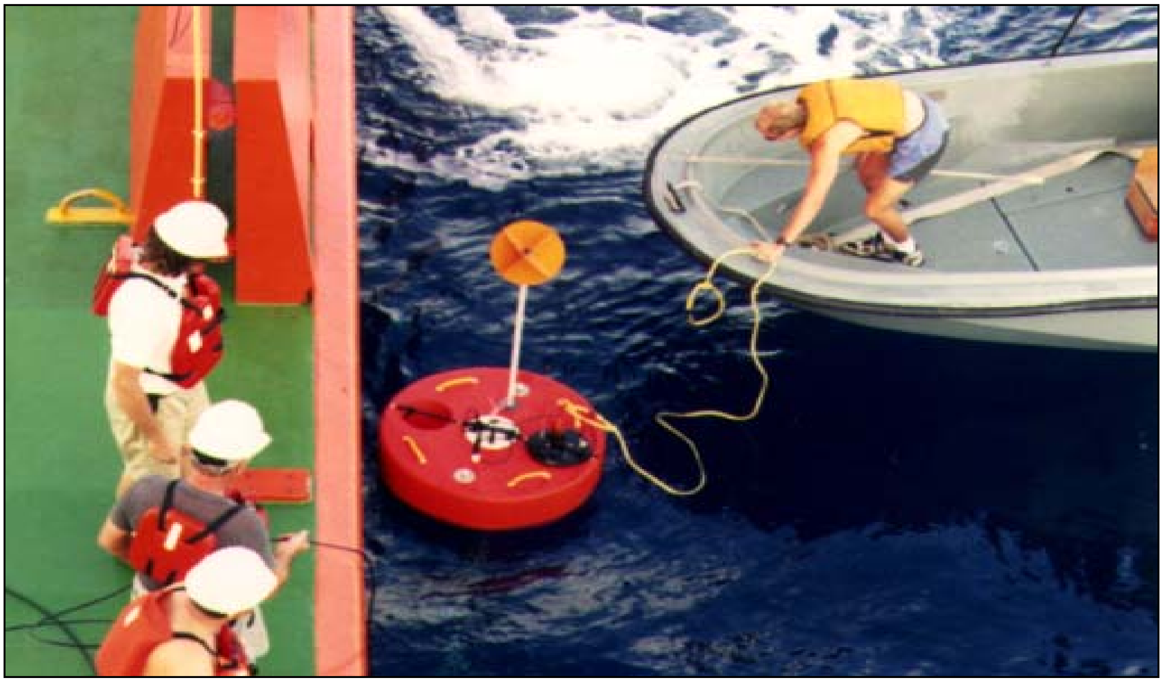

Figure 2-6. RF telemetry buoy being deployed.

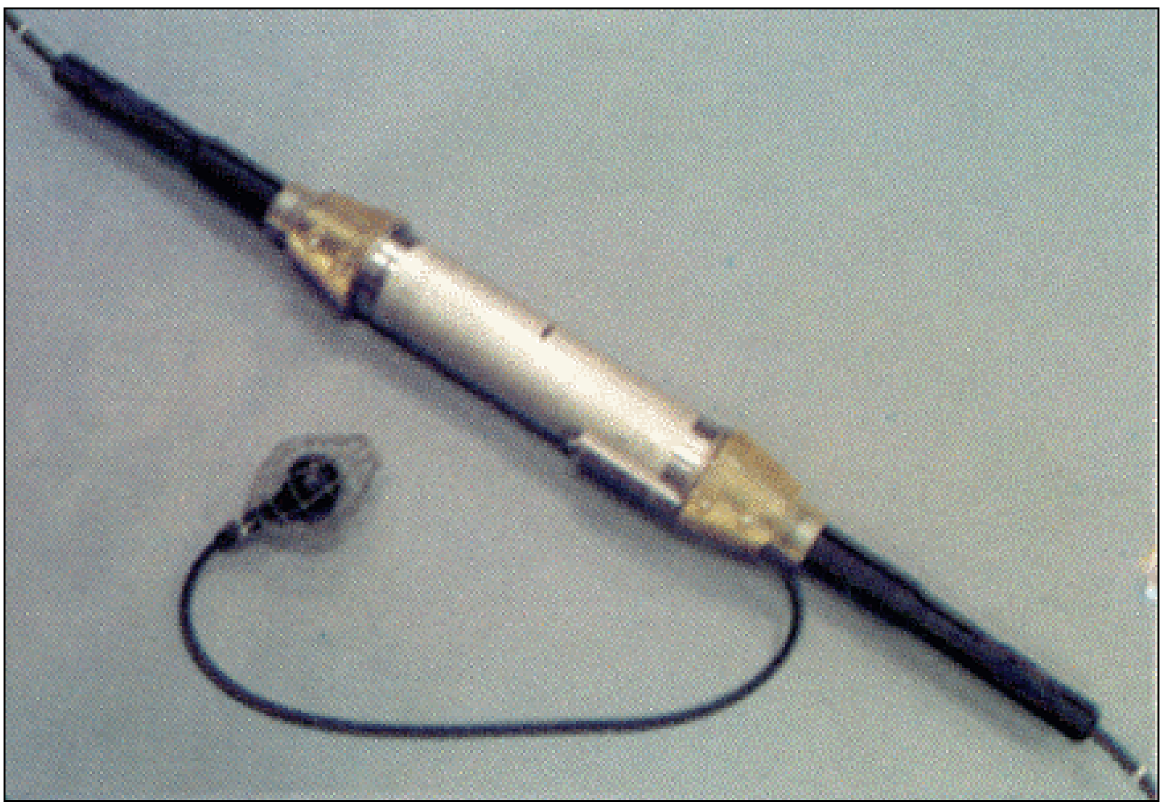

Figure 2-7. In-Line multiplexed sensor node and hydrophone.

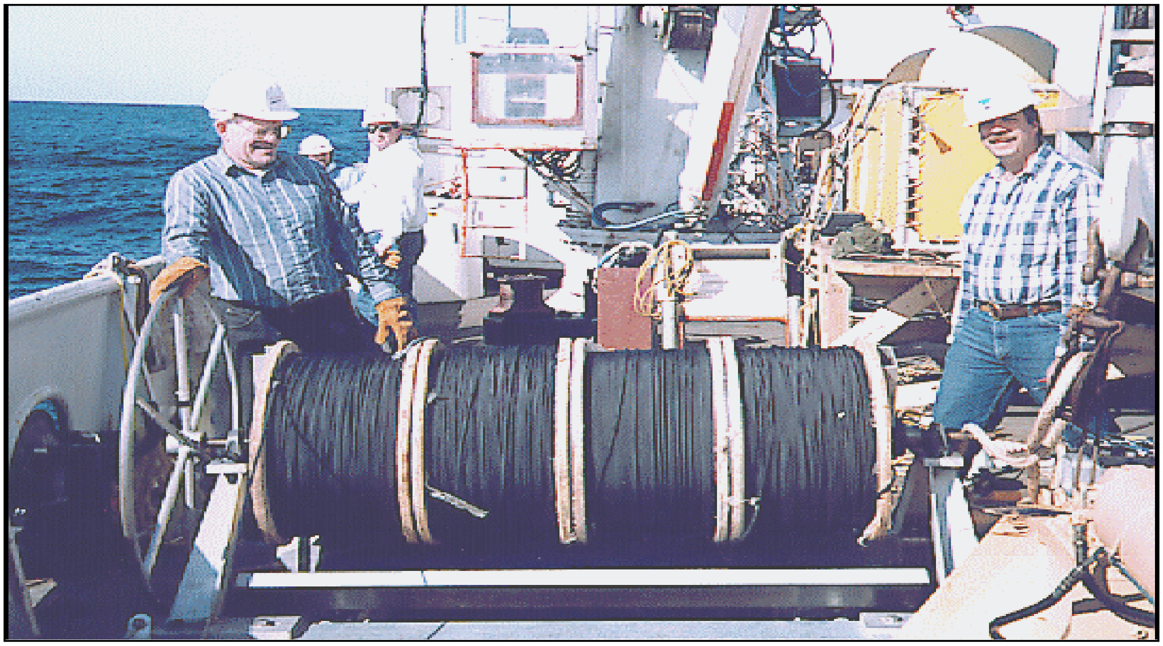

Figure 2-8. Cable deployment operation.

Figure 2-9. Station-keeping buoy being deployed.

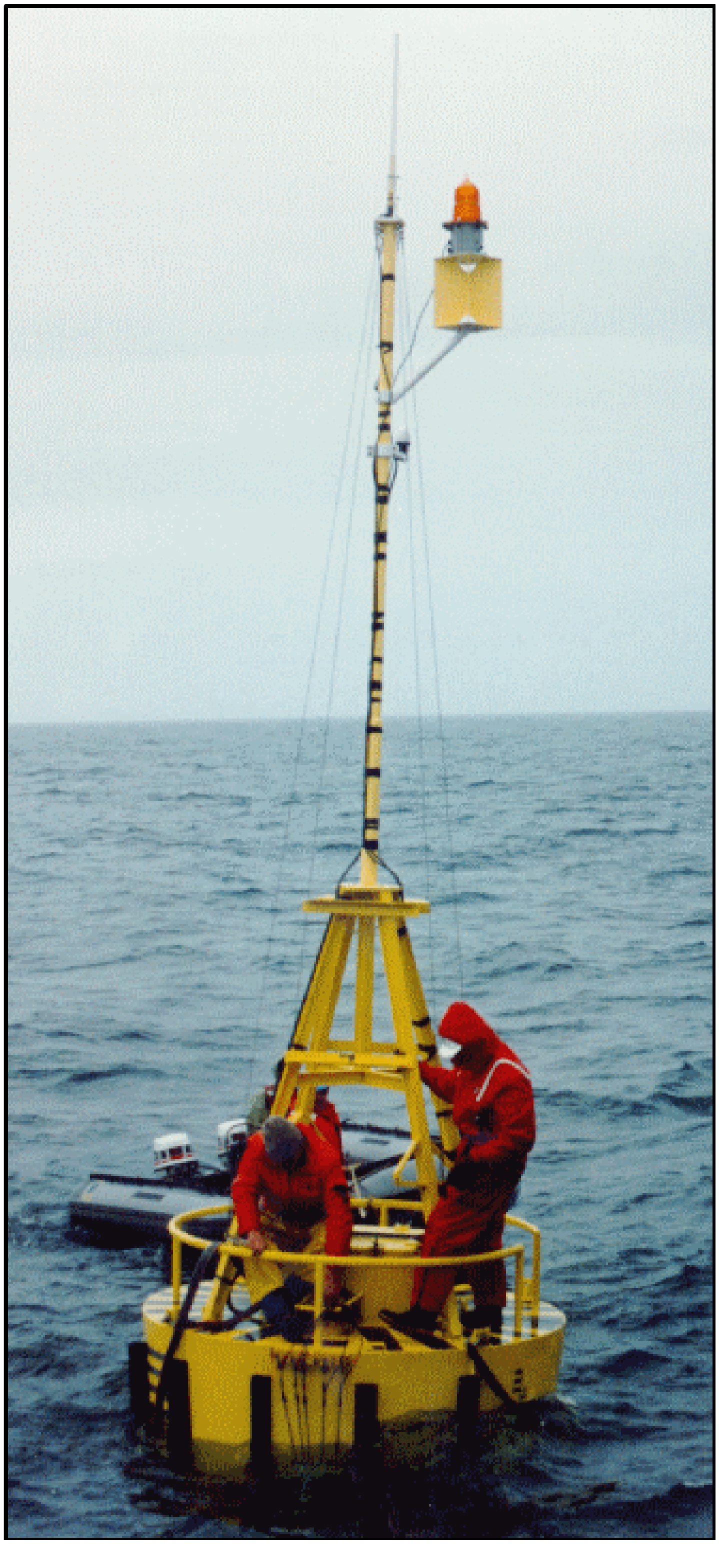

Figure 2-10. Connecting the sensor cables to a portable range termination and telemetry buoy.

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CHAPTER 3

SUMMARY OF EXISTING INTERIM AND TRANSPORTABLE SHALLOW-WATER RANGE SYSTEMS AND THEIR SALIENT CHARACTERISTIC FEATURES

3.6 Instrumentation "Toolset"

The Naval Undersea Warfare Center (NUWC) Keyport and Newport Divisions have developed a shallow-water range "toolset" containing a variety of interim and transportable range instrumentation. These tools provide capabilities to address short-term or long-term needs for temporary ranges in surrogate or convenient locations for T&E or small-area training exercises. Some of the key characteristics of the toolset are listed in Table 3-1.

TABLE 3-1. EXISTING INTERIM AND TRANSPORTABLE SHALLOW-WATER RANGE SYSTEM SALIENT CHARACTERISTICS

Range Type	Water Depth (ft)	No. of Tracking Sensors	Comments
Portable Tracking System (PTS)			
In-line, multiplexed sensor array	100 - 2,000	2 arrays, 4 - 50 sensors per array	Very robust; can be cabled to a moored ship or shore site; for short or long-term use.
Radio-linked, buoyed, sensor array, moored	50 - 500	Up to 30	Low cost, quick to deploy and recover; typically for short-term use.
Station Keeping Buoy (SKB) System	25-15,000+	Typically up to 7 (more are possible)	Medium cost, easy to deploy, can autonomously station keep to one spot without mooring lines.
Transponder -based sensor system	50-10,000+	Typically in groups of 7	Easy to deploy. Can be used with a moored relay buoy or an SKB surface buoy link.
Free-Drifting surface buoy sensor system	25-15,000+	Typically up to 16	Very small GPS enabled sonobuoy type units. Very easy to deploy. Low cost.
Shallow-Water Inexpensive Flexible Tracking (SWIFT):			
Individually-cabled sensors, for low-risk environments	5 - 5,000	Typically up to 16	Low-cost coaxial cables connected to a moored ship or a shore site.
Individually-cabled sensors, for high-risk environments	5 - 5,000	Up to 16	Various configurations of cables, buoys, and sensors connected to a ship or shore.
Star-multiplexed sensors, for short or long-term use	5 - 5,000	Up to 16 per multiplexer unit	Sensors cabled to a multiplexer with a trunk cable to a moored ship (off-range) or a shore site.
Star-multiplexed using a long-term, remotely-controlled telemetry buoy	5 - 2,500	Up to 8 per telemetry buoy	Sensors cabled to a robust, moored, termination & radio-telemetry buoy.
Radio-linked, buoyed, sensor array, moored	5 - 5,000	Typically up to 16	Low-cost, quick-to-deploy and recover; typically for short-term use.
Radio-linked, buoyed, sensor array, free-drifting	25 - 15,000+	Typically up to 16	Low-cost, quick-to-deploy and recover; typically for short-term use.

3.7 Portable Tracking System (PTS)

The PTS has been developed as a transportable range, having as many as 100 hydrophone sensors, divided between two multiplexed electro-optical string arrays. Depending on water depth, the typical tracking coverage area is generally from 50 to 100 square nautical miles (nmi^2). The array cables terminate at the range operations center, which houses the signal processor and tracking and display computers. The range operations center can either be placed on the deck of a moored ship or placed on shore.

In October 1997, a PTS range with a string of 50 sensors was deployed off the coast of Great Stirrup Cay in the Bahamas. This range has attained approximately 90 nmi^2 of track coverage. Surface and in-air vehicle tracking is accomplished with Global Positioning System and Large Area Tracking Range (GPS/LATR) equipment. Water depths vary from 100 to 1500 feet, with an average water depth of 900 feet.

To supplement the in-line multiplexed array system, a much smaller and more portable PTS option individually deployed radio-linked surface buoys. The hydrophone sensors for these buoys were cabled down to just above the mooring anchors. The RF telemetry utilized sonobuoy-based Very High Frequency (VHF) band and channel assignments. These buoys could be brought in and out of sleep-mode by a control unit located the on the range operation ship. The ability to remotely activate the buoys conserved battery power. These buoys are usually referred to as the Buoyed Acoustic Radio Frequency (RF) Telemetry (BART) buoy system.

3.8 Shallow-Water Inexpensive Flexible Tracking (SWIFT) Ranges

The increased emphasis on testing and training in a variety of shallow/littoral ocean environments has increased the Navy’s need for relatively short-term, portable ranges that can be deployed and recovered quickly and economically. To meet the increased need, the technology of the Quinault range site was developed to create a transportable range system architecture that relies on proven technologies and many commercial off-the-shelf (COTS) components. The newly developed transportable range system was designated as the SWIFT Range system.

The SWIFT Range system consists of a family of shallow-water range components designed to satisfy the various requirements of cost, reliability, longevity, durability, ease of installation, and convenience of operation. The tracking sensors can be rugged, long-life units, the Quinault-style units, or they can be low-cost, lightweight units designed for short-term applications. Cable options include heavy-armored quad cable, type SX-220 heavy-duty coaxial cable, small armored coaxial cable, or small, strengthened, lightweight, coaxial cable. Sensor array cables can be terminated into a central multiplexer unit, with a trunk cable leading to shore, to a boat or barge moored near the range site, or via a central radio telemetry buoy. When a short-term range is needed, individual radio-linked sensor buoys can be employed to eliminate the long cable runs. SWIFT ranges provide integrated, real-time underwater and above-water tracking of multiple exercise participants such as ships, submarines, torpedoes, targets, and aircraft. Differential Global Positioning System (DGPS) is used for tracking surface and above-water objects as well as for surveying the range sensor locations to ensure precise underwater tracking.

SWIFT range systems have been deployed in both deep and shallow water at a number of Pacific Ocean sites including Hawaii, Nova Scotia, British Columbia, and Taiwan. The range tracking equipment and displays are usually set up in available shipboard spaces or in a shore facility near the range. However, some systems have been remotely operated from thousands of miles away by using encrypted data links.

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CHAPTER 4

SUMMARY

The Naval Underwater Weapons Center (NUWC) has applied a variety of technologies to address test and evaluation challenges for instrumenting shallow undersea test areas, to conduct tracking, and to perform acoustic monitoring and measurements. The systems and components presented in this document can meet a wide variety of requirements for ranges, and similar requirements of portable acoustic systems at worldwide locations.

Diagrams of some of the technologies and systems discussed in this document are shown on the following pages as:

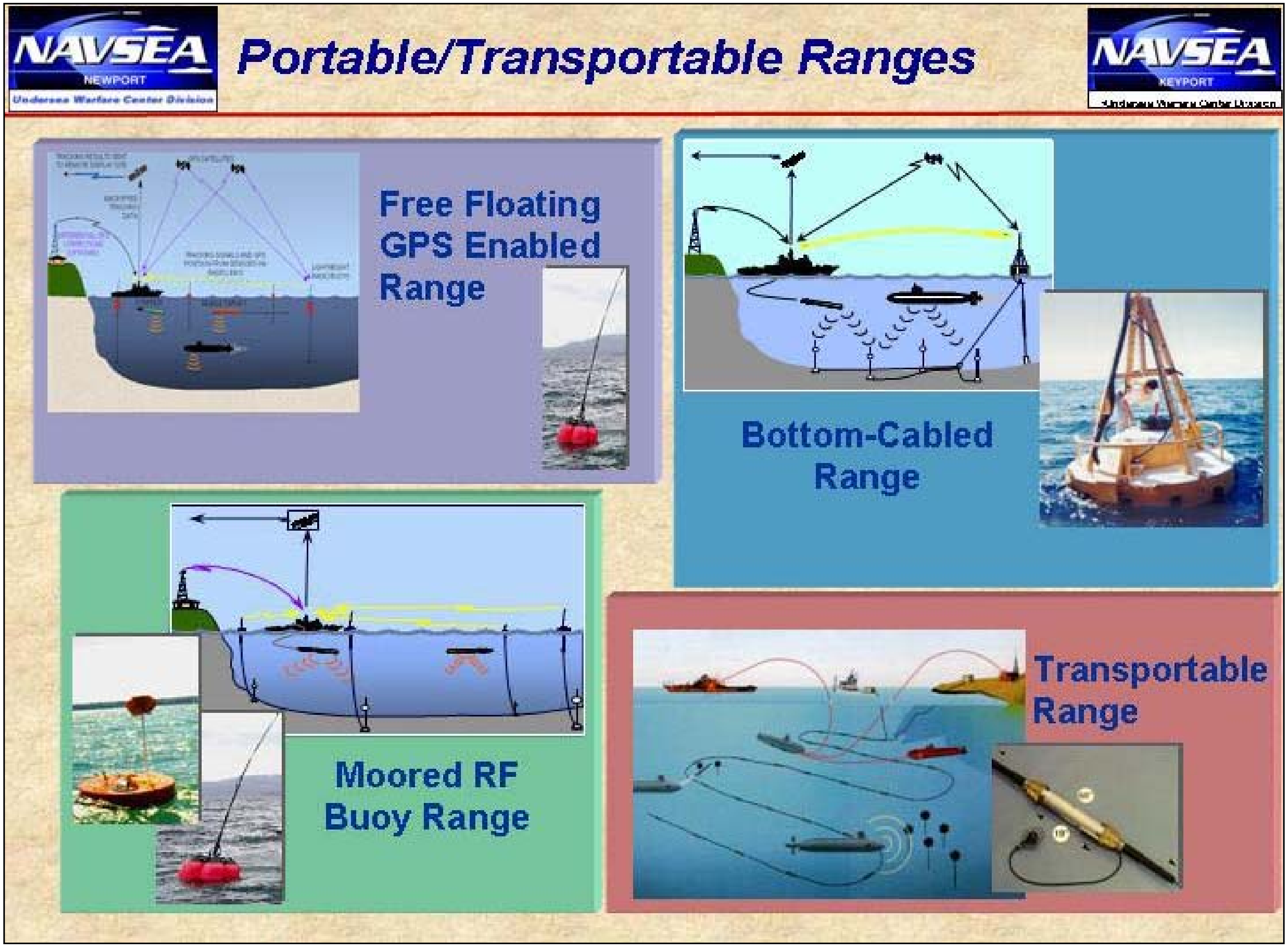

Figure 4-1. Portable/transportable ranges.

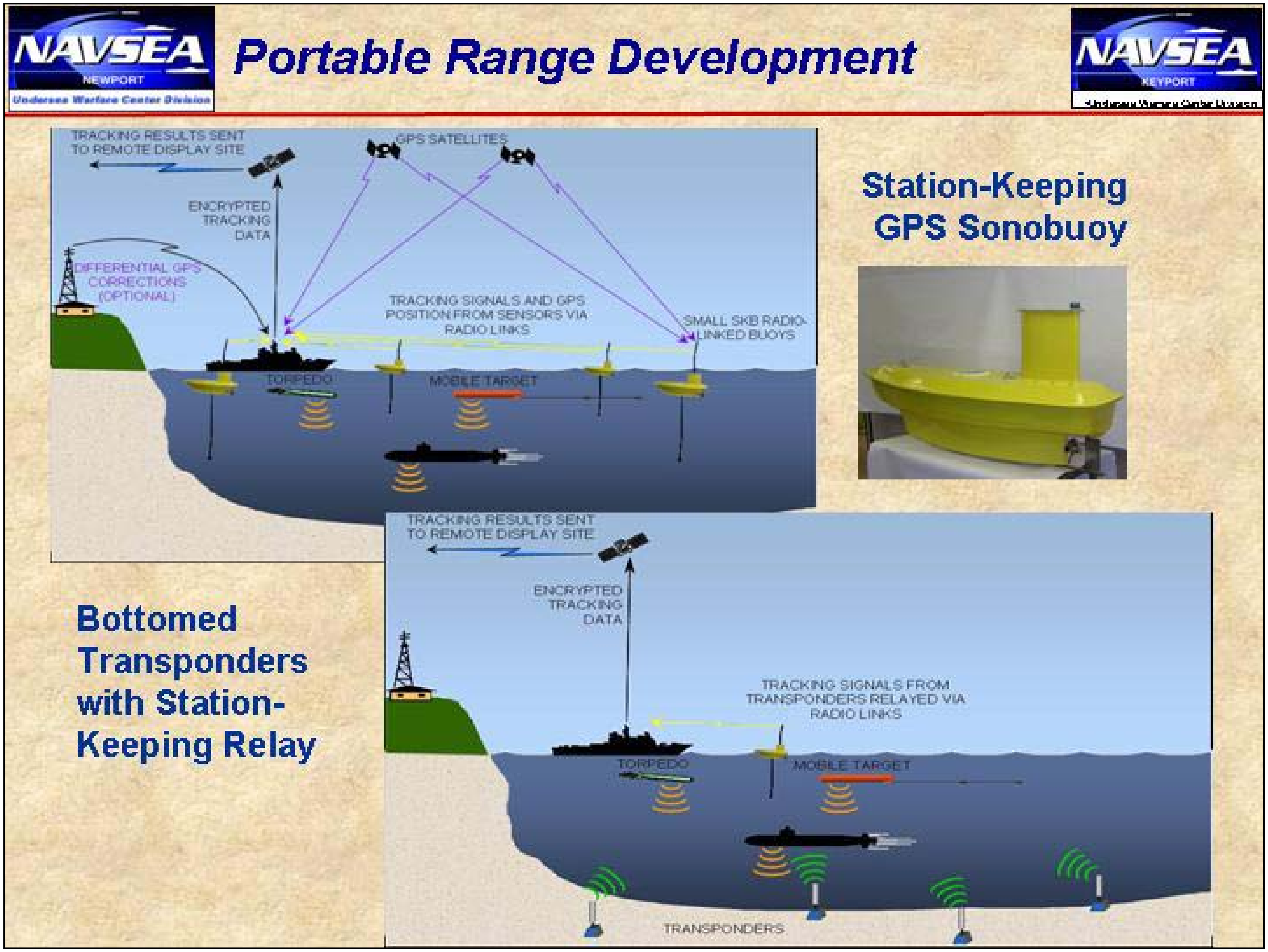

Figure 4-2. Portable range development.

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APPENDIX A

UNDERWATER SYSTEMS GROUP: TASK USG-17

Assigned: August 2003

1. **TITLE:** Portable Range Technologies

2. **SCOPE AND SPECIFIC OBJECTIVES:** This task is to document the different methods and systems now being used or developed to perform portable range tracking functions.

3. **UTILITY OF END PRODUCT:** This report will facilitate the decision process on selecting the type of portable range system best suited for a particular application taking into account site and environmental specific information. The pro and cons of each system will additionally be highlighted in a matrix of attributes against range requirements.

4. **APPROACH:** Solicit inputs from the USG associate and member ranges as to what systems have been employed, or now being developed for portable range applications. Collect responses and prepare a final report.

5. **ADDITIONAL COORDINATION REQUIRED**: A survey questionnaire/outline will be distributed through the RCC-USG. The preliminary report will be distributed through the RCC Secretariat. After being reviewed by the associate and member ranges, a final report will be submitted.

6. **RESOURCES REQUIRED:** N/A

7. **TOTAL COST ESTIMATE:** N/A

8. **MILESTONES:**
   a. Task Proposed .... April 03
   b. Task Assigned .... September 03
   c. Survey Outlined .... Nov 03
   d. Responses Processed .... Jan 04
   e. Preliminary Report .... June 04
   f. Review Comments .... August 04
   g. Final Report .... October 04

9. **NAMES, ORGANIZATIONS, AND PHONE NUMBER OF TASK CHAIRS:**
   a. Dennis Desharnais, NUWCDIVNPT, 401-832-1071
   b. Neal Prator, NUWCDIVKPT, 360-396-7669

10. **COMPLETION DATE:** October 2004